US 20030221870A1

(19) United States
(12) Patent Application Publication
Johnson, JR.
(10) Pub. No.: US 2003/0221870 A1
(43) Pub. Date: Dec. 4, 2003

(54) EARTH LOOP HEAT EXCHANGE METHODS AND SYSTEMS

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(21) Appl. No.: **10/161,332**

(22) Filed: **Jun. 1, 2002**

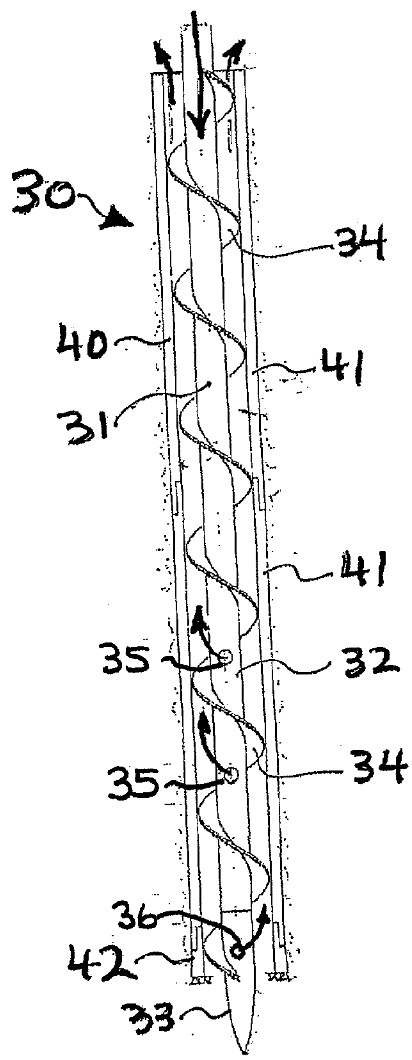
Publication Classification

(51) **Int. Cl.**[7] **E21B 7/20**

(52) **U.S. Cl.** **175/71**; 175/173; 175/203; 175/305

(57) **ABSTRACT**

A method and system for drilling creating a wellbore which, in at least certain aspects, includes positioning a drilling apparatus at a desired location at the earth surface, the drilling apparatus having rotating and hammering apparatus for simultaneously rotating and hammering a dual tubular string into the earth, the dual tubular string with an outer casing string spaced apart by an annular space from an inner drill pipe string, both the outer casing and inner drill pipe string being hollow, a drill bit secured to a lowermost end of the inner drill pipe string and, optionally, a casing drill apparatus secured at a lowermost end of the casing string, drilling through the earth to form the wellbore by simultaneously rotating and hammering the dual tubular string with the drilling apparatus; and, in certain aspects, installing a geothermal heat loop and grouting the space around it.



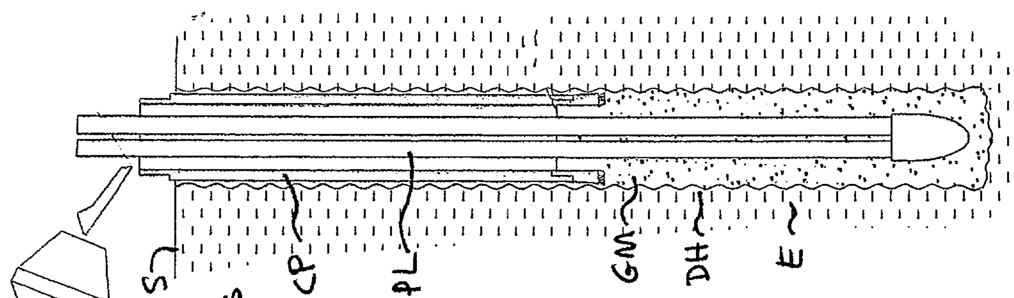


Fig. 5

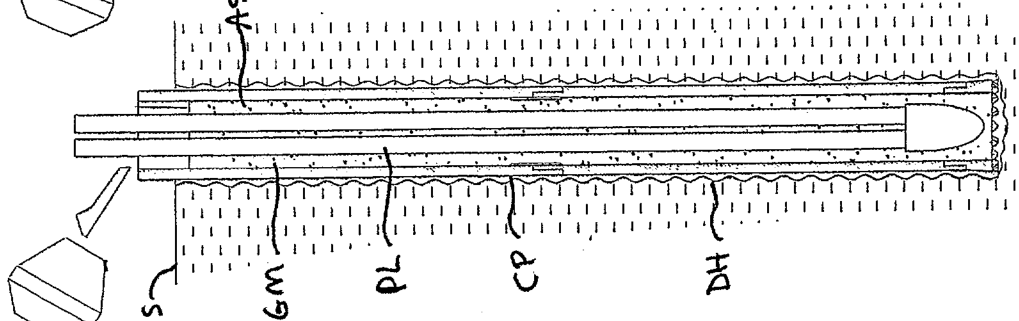


Fig. 4

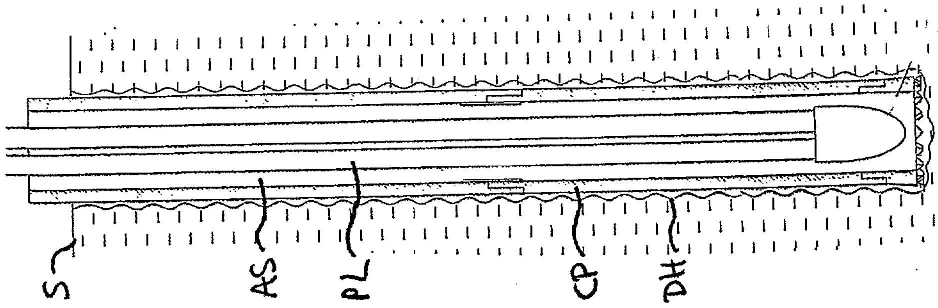


Fig. 3

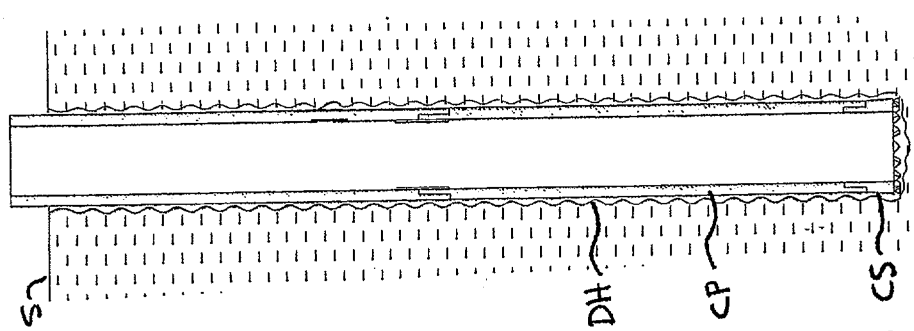


Fig. 2

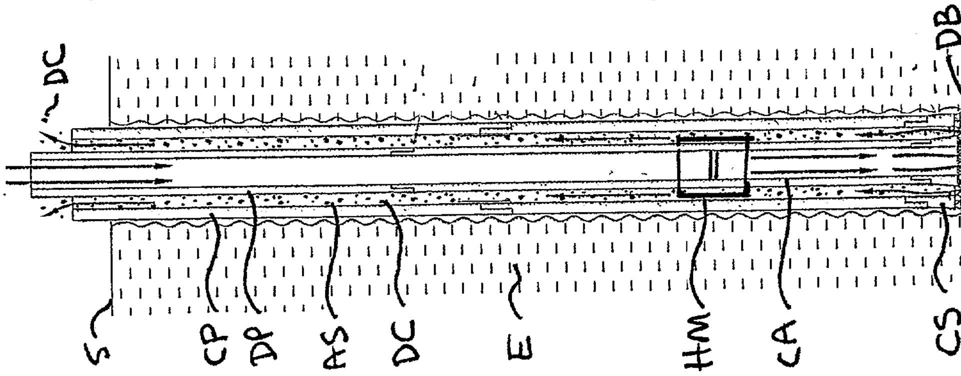


Fig. 1

Fig. 6A

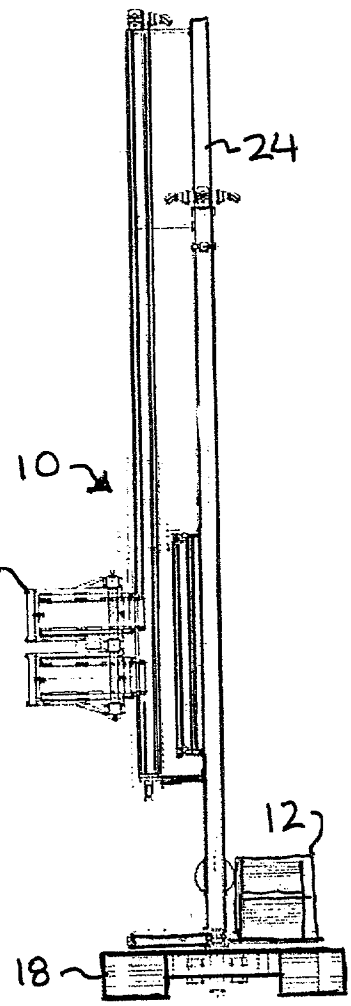
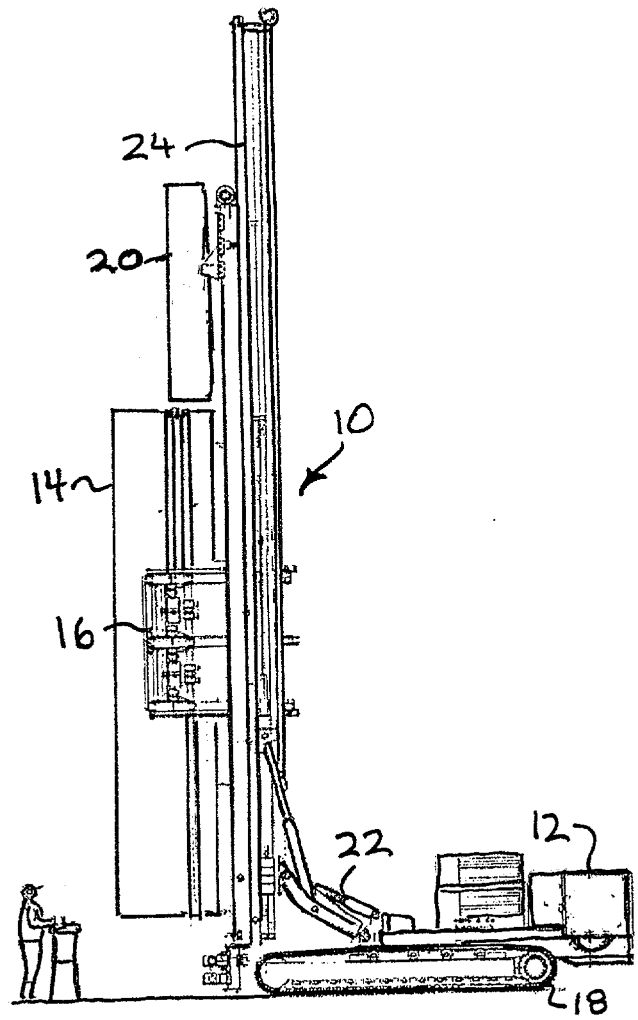


Fig. 6B



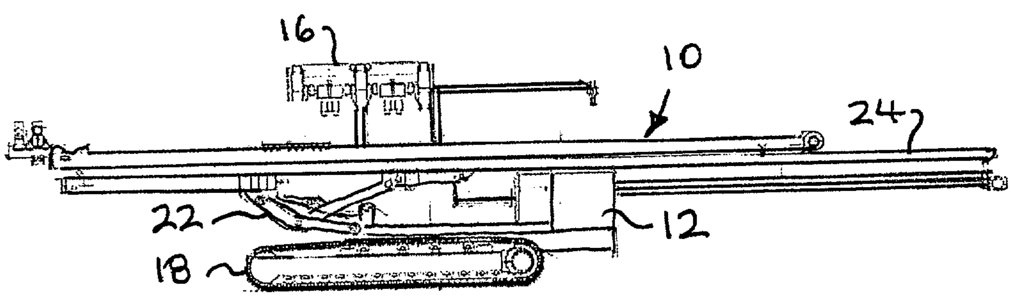
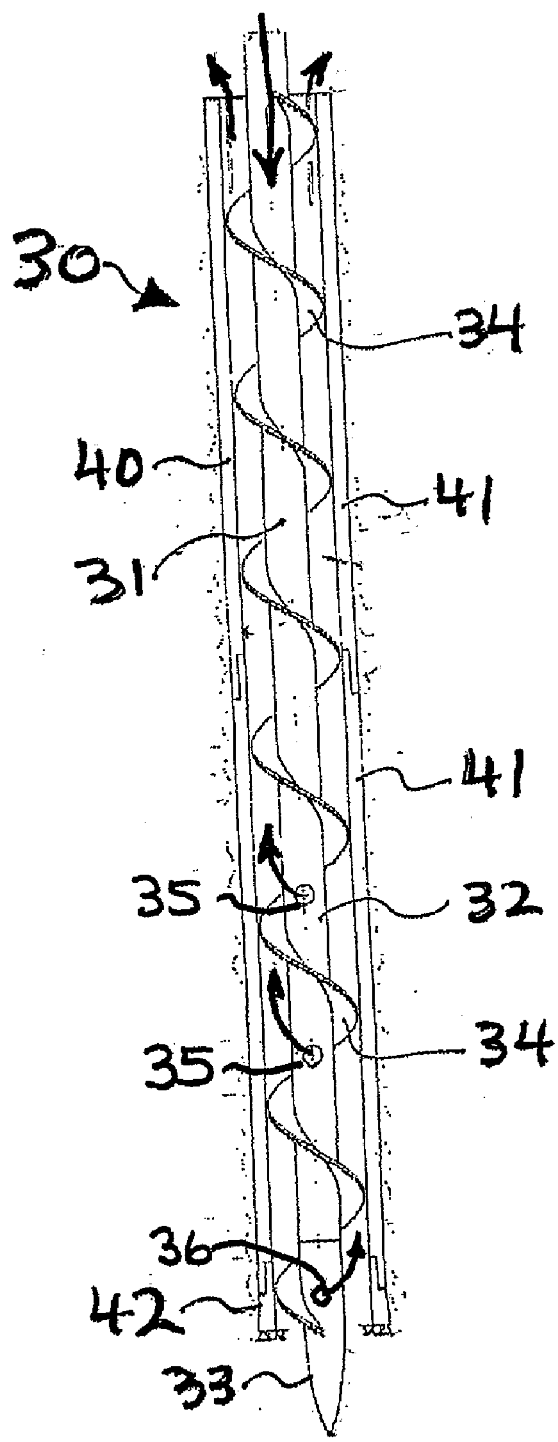


Fig. 6C

Fig. 7



EARTH LOOP HEAT EXCHANGE METHODS AND SYSTEMS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention is directed to underground heat exchange systems; to apparatus and methods for drilling wellbores for such systems; and to installing such systems.

[0003] 2. Description of Related Art

[0004] Earth loop energy transfer systems are well known, as are methods for drilling boreholes into which such loops are installed and methods for installing the loops. In such systems, heat is exchanged with the earth using a closed loop pipe or series of closed loop pipes buried in the ground through which a heat transfer fluid is circulated. There is no direct contact of the fluid with the earth. An exchange of heat occurs if there is a difference between the temperature of the fluid circulating in the pipe and the earth temperature,—primarily by conduction through the wall of the earth loop. If a system is operating in a heating mode, heat is taken from the fluid inside of this circulating loop, e.g. by a heat exchanger in heat pump equipment. If the system is operating in a cooling mode, the heat exchanger puts heat into the circulating fluid. The earth stays at a relatively constant temperature, providing an almost limitless resource as a heat supplier and heat sink.

[0005] A wide variety of systems and apparatuses for drilling wellbores and for installing ground heat exchange pipe loops in a wellbore are known in the prior art. The application of circulating water through pipes in the earth as a heat sink/source for water source heat pumps is well known. It has also been established that the energy efficiency of such a geothermal heat pump system is far superior to the traditional HVAC alternatives of air source heat pumps, boilers, chillers, furnaces, etc., often requiring 50% less energy to operate. Often a significant amount of the initial cost of such an earth heat exchange system is due to the drilling and construction costs of the wellbore and the earth loop heat exchanger.

[0006] In several prior art methods, the construction of an earth loop heat exchanger includes drilling a borehole 150' to 500' deep, inserting a small diameter (usually 0.75" to 1.25" diameter) polyethylene pipe loop, and grouting the loop in place. Trenches are then dug between the boreholes and the loop ends are manifolded together in parallel, and connected to a common header, which is in turn connected to the heat pumps. Water is then circulated through this closed loop system, and heat is absorbed from or rejected to the earth, as the heat pumps require. A typical earth loop heat exchanger design for a small facility might require drilling 100 holes at 300' deep, while a large facility might require 1000 holes. High drilling rates and consistent production is fundamental to keeping down the costs of the earth heat exchanger.

[0007] The type of drilling system for a geothermal heat exchanger often requires both a high number of holes and holes which are relatively deep. Drilling technology used in other drilling applications may not be preferable for geothermal applications. For example, quarry drilling, seismic drilling, and construction drilling all require high numbers of holes in a relatively compact geographic area, but the holes required are relatively shallow in depth, usually less than 100' deep. In water well drilling and geotechnical investigation drilling, holes are drilled deeper, but they are relatively small in number and emphasis is on sampling, logging, packing, and other completion steps, not on high production drilling.

[0008] Drilling rigs are usually designed to drill optimally in only one specific type of formation. Unconsolidated formations such as sand/clay/gravel formations are usually drilled best using mud rotary techniques and consolidated formations such as limestone, sandstone, granite, etc., are most efficiently drilled using percussion methods. Since lithologies can change drastically, even in fairly small geographic areas, it is often necessary for a drilling company to own and operate both mud rotary and percussion drill rigs and/or tooling. And in many circumstances, the lithology of the formation being drilled changes with depth, and can require a combination of drilling techniques and equipment to be employed on the same borehole. A typical mud rotary drill system utilizes a drilling mud mixing/circulation system incorporating duplex or triplex mud pumps. Drilling "mud" is pumped down through a rotating drill stem and through the drill bit as the drill string is being rotated. The cuttings produced by the drill bit are transported by the drilling mud up the annulus between the drill pipe and the sides of the earth borehole wall. In addition to transporting the drill cuttings and lubricating and cooling the drill bit, the drill mud attempts to keep the hole from collapsing by virtue of the hydrostatic pressure exerted by the weight of this liquid mud column. However, in many cases the hydrostatic pressure exerted by the mud is not sufficient to offset the pressure existing in the formation being drilled. Sand, gravel, and other material may be forced into the hole during drilling resulting in the "over-excavation" or "mining out" of the borehole. This "over-excavation" can be hazardous to surface structures or equipment and also results in slow drilling progress as well as increasing the grouting costs. In many soil conditions, an unstable borehole collapses as soon as the drill pipe is withdrawn from the bore, thus preventing the insertion of the heat exchanger pipe loop. If "hard, ""rock," or "consolidated" conditions are encountered using the mud rotary method, drilling progress slows down significantly. Similarly, if very unstable soil conditions are encountered, the mud weight must be regulated carefully to prevent hole collapse and/or "mining" from occurring. In many types of geology, "thief zones" or voids are encountered which cause "lost circulation" problems resulting in "stuck" drill pipe. Constant mud regulation and the use of other methods to preserve hole integrity can slow drilling progress significantly.

[0009] The production rate in mud rotary applications can vary widely, not only as a function of the geology, but also due to the expertise of the driller. The driller must: know when to thicken or thin the drilling mud; which drill bit to select; what rotation speed to use; how much circulation time is required to build a "wall cake;" what additives to add to the mud; how much down-force to use; maintain lost circulation vigilance; etc.—and these variables can change significantly as the lithology through which he is drilling changes with increasing depth. In addition, mud rotary drilling can significantly increase the thermal resistance of the borehole in the near-wellbore area by hydrostatically forcing drilling mud into a permeable formation and by building a "wall-cake" of drilling mud (e.g. bentonite) on the borehole wall thus requiring additional holes to be drilled.

[0010] At another extreme, hard formations such as limestone, sandstone, granite, etc. are usually drilled most economically with downhole (or "down-the-hole") hammers and compressed air systems. While the walls of a "rock" borehole are essentially stable and do not require the hydrostatic pressure of drilling mud to keep them from collapsing, layers or "seams" of unstable soil conditions such as sand or gravel are frequently encountered while drilling a predominately rock formation. Even where drilling conditions are predominantly solid rock, there is usually a layer of unconsolidated "overburden" on top of the rock which must be penetrated before downhole hammers can effectively begin to drill the rock. As the hole is drilled, air pressure from the drilling operation "pressures up" in the mud seams and any unconsolidated lithology. When the drill pipe is removed from the drilled borehole, the built up air pressure in the mud seams and unconsolidated portions of the formation will force this soft material into the borehole as the pressure attempts to relieve itself by escaping up the borehole, effectively blocking the borehole before the plastic heat exchanger pipe can be inserted. Since the plastic pipe cannot be "pushed" down through these blockages, the drill rig must be repositioned on the borehole, and the hole must be cleaned out, resulting in expensive delays and low production. In an attempt to keep the drilled holes from collapsing, casing pipe, usually steel, must be inserted into the drilled borehole, at least through the overburden and down into the rock. If the overburden is not stabilized with casing, the top portion of the hole will erode or be "mined out" as the rock underneath is drilled, in extreme cases causing the drill rig to capsize. If the rock formation has fractures, caverns, flowing sand, mud seams, or any other condition which can cause the hole to close up or bridge before the heat exchange pipe can be inserted and grouted, it may become necessary to "case" the hole from top to bottom. In traditional drilling operations, casing the hole requires three separate steps. First the hole is drilled, then the casing is pushed or even "drilled" down through the pre-drilled and often partially collapsed hole, and, finally, any debris remaining inside the casing is cleaned out by "drilling" inside the casing. The expense of this type of drilling can make a geothermal project very or prohibitively expensive.

[0011] In many geothermal applications, it is necessary to case a geothermal borehole only temporarily. Once a heat exchanger pipe has been inserted and grouted in place, the casing can be removed. Not only is permanent casing expensive, it can also inhibit the thermal transfer of heat between the heat exchanger pipe and the earth. Even when sophisticated drilling machines and carousels or magazines "automatically" handle the drill pipe, casing pipe is usually handled manually. In many cases, the casing pipe sections are welded together going in the hole and cut apart with a torch as they are extracted from the hole because the drilling machines lack the tooling to efficiently screw together both drill pipe and casing, each having different diameters. Loading heavy and clumsy casing pipe is a physically demanding and hazardous job requiring additional labor. The logistics of handling the casing pipe at the surface usually dictate the use of additional surface equipment thereby incurring additional equipment rental and labor costs.

[0012] Systems for simultaneously advancing casing while drilling, such as the "ODEX" system are well known. In such systems, a "collapsible" or sacrificial drill bit is attached to the end of the drill pipe and drills a hole slightly larger in diameter than the casing. Normally, the casing rides on the back shoulder of a special drill bit assembly and follows directly behind the drill bit as the hole is being drilled. The casing actually does no drilling—it only follows the pre-drilled hole. Once the desired depth is reached, the drill bit, usually one of an eccentric design, is "collapsed", usually by reverse rotation of the drill pipe, so that the drill bit is now smaller in diameter and can now be extracted back up through the casing as the drill pipe is withdrawn. When a "sacrificial" drill bit is used, it is disconnected from the end of the drill pipe by any of several well known remotely actuated mechanisms, and the drill pipe is extracted from the cased borehole, permanently abandoning the sacrificial drill bit. Most of these well known simultaneous drilling and casing systems are often both slow and expensive and are often used as a method of "last resort." Drilling progress is slow with these casing advance systems as compared to the present invention for three primary reasons. Firstly, the employ only one drilling element, the drill bit. Secondly, there are only two sources of drilling energy—1) the rotation of the inner drill string, and 2) the energy of the air compressor (if a down-the-hole hammer is being employed). And thirdly, the casing is customarily handled manually, which is slow and hazardous.

[0013] As the drilling depths become deeper and deeper, casing extraction becomes more and more difficult. Conventional drilling methods often rely entirely on the "pullback" capability of the drill rig to extract casing. In many cases the pure "pullback" force necessary to extract the casing exceeds the capability of conventional rigs, and, in extreme cases, the pullback force required can exceed the longitudinal tensile strength of the casing.

[0014] The prior art discloses numerous in-ground heat exchanger systems; grouts; and grouting systems (see, e.g. U.S. Pat. Nos. 5,435,387; 5,244,037; 5,261,251; 5,590,715; 5,758,724; and 6,276,438; 6,041,862; 6,250,371;—all of which patents and all references cited therein are incorporated here fully for all purposes.

[0015] There have long been needs, recognized by the present inventor for: effectively and efficiently constructing a completed geothermal earth heat exchanger borehole under a wide variety of geological conditions; making a wellbore for an earth heat exchange loop with methods that reduce equipment and labor requirements; making a wellbore into which an earth loop can be installed without the wellbore collapsing; installing such a loop without snagging the loop on parts of the wellbore; and grouting effectively around such a loop.

SUMMARY OF THE PRESENT INVENTION

[0016] The present invention in at least certain embodiments provides new systems and methods using dual coaxial tubulars so that a wellbore for an earth heat exchange loop is cased as it is drilled. In certain aspects inner drilling apparatus is removed after the wellbore has been drilled, leaving casing in place to prevent collapse of the wellbore and to facilitate installation of the heat exchange earth loop in the wellbore. Following insertion of the loop into the wellbore, a grout mixture is fed around the loop. Optionally, the casing is removed and, if desired, additional grout is fed into the wellbore as the casing is removed. In one particular aspect, the casing is removed before feeding grout into the wellbore; and in one aspect of such a method, grout is introduced from the bottom up through a conduit or pipe, e.g., but not limited to, a tremmie pipe.

[0017] In certain embodiments according to the present invention, a system is provided that is track mounted for ease of transport, positioning, and handling and manipulation. In certain aspects, such a system has: an erectable mast to which are secured an hydraulic percussion hammer apparatus for rotating and impacting the coaxial drill tubulars and forcing them into the earth; and automatic drill rod and casing handling apparatus to quickly and safely connect drill rods and casing tubulars without additional labor. Any suitable known drill bit or drilling apparatus may be used. Preferably, the lower end of the casing is treated with drilling material and/or has drill teeth or drilling projections thereon so that, with the drill bit, a compound lower drilling apparatus is formed. In one particular aspect a known casing shoe is connected to the end of the casing.

[0018] The present invention provides, in certain aspects, methods by which a geothermal borehole may be drilled and completed in virtually any type of geological formation (hard rock, soft sand, clay, gravel, or a combination of these materials) by using only one type of properly tooled drilling machine, and employing a reduced number of personnel.

[0019] The present invention, in certain aspects, provides methods which employ two drilling elements, a drill bit on the end of an inner drill pipe, and a drilling shoe on the end of casing. Rotational energy is applied to both the drill pipe and the drill casing. Optionally, a high energy "rotary percussion drill head," such as the commercially available Krupp HB 60, is used which simultaneously applies hammering and rotational energy to the drill pipe and the casing pipe, substantially increasing drilling speeds. When a down-the-hole hammer and a high-pressure air compressor are employed, methods of the present invention utilize two drilling elements and four sources of drilling energy and can use a completely automatic drill pipe and drill casing handling system. A section of drill pipe and casing pipe can, in certain aspects, be automatically and safely added to the drill string in less than 30 seconds, without the requirement of additional equipment or personnel.

[0020] The present invention, in certain aspects, provides a "back-hammering" capability with the hydraulic percussion head (e.g. a Krupp HB 60). The drill operator may activate this feature via a selector switch to "hammer" the casing in the "up direction," greatly reducing the pullback force necessary to extract "stuck" casing. Without this feature, entire casing strings are often permanently stuck. The hydraulic percussion head also provides vibratory action during casing extraction operations. After a plastic pipe loop has been inserted into the casing and the casing has been filled with grout material, the vibratory action of the "up-hammering" feature has the benefit of compacting the grout (similar to vibrating concrete), thus removing entrapped air and thereby increasing the grout's thermal transfer properties. Increasing the thermal conductivity of the grout increases the thermal efficiency of the borehole and results in a reduction of the number of boreholes that must be drilled on the project.

[0021] It is, therefore, an object of at least certain preferred embodiments of the present invention to provide:

[0022] New, useful, unique, efficient, nonobvious systems and methods for drilling a borehole into which an earth heat exchange loop is to be installed, and, in at least particular embodiments, drilling methods that employ coaxial drilling tubulars (e.g. drill pipe or drill rod and casing) being rotated simultaneously;

[0023] New, useful, unique, efficient, nonobvious systems and methods for installing such a loop in such a wellbore;

[0024] New, useful, unique, efficient, nonobvious systems and methods for grouting such a borehole during and/or following loop installation; and

[0025] New, useful, unique, efficient, nonobvious earth loop heat exchange systems installed using such systems and methods.

[0026] Certain embodiments of this invention are not limited to any particular individual feature disclosed here, but include combinations of them distinguished from the prior art in their structures and functions. Features of the invention have been broadly described so that the detailed descriptions that follow may be better understood, and in order that the contributions of this invention to the arts may be better appreciated. There are, of course, additional aspects of the invention described below and which may be included in the subject matter of the claims to this invention. Those skilled in the art who have the benefit of this invention, its teachings, and suggestions will appreciate that the conceptions of this disclosure may be used as a creative basis for designing other structures, methods and systems for carrying out and practicing the present invention. The claims of this invention are to be read to include any legally equivalent devices or methods which do not depart from the spirit and scope of the present invention.

[0027] The present invention recognizes and addresses the previously-mentioned problems and long-felt needs and provides a solution to those problems and a satisfactory meeting of those needs in its various possible embodiments and equivalents thereof. To one of skill in this art who has the benefits of this invention's realizations, teachings, disclosures, and suggestions, other purposes and advantages will be appreciated from the following description of preferred embodiments, given for the purpose of disclosure, when taken in conjunction with the accompanying drawings. The detail in these descriptions is not intended to thwart this patent's object to claim this invention no matter how others may later disguise it by variations in form or additions of further improvements.

DESCRIPTION OF THE DRAWINGS

[0028] A more particular description of embodiments of the invention briefly summarized above may be had by references to the embodiments which are shown in the drawings which form a part of this specification. These drawings illustrate certain preferred embodiments and are not to be used to improperly limit the scope of the invention which may have other equally effective or legally equivalent embodiments.

[0029] FIGS. **1-5** are side schematic views of steps in a method according to the present invention.

[0030] **FIG. 6A** is an end view of a drilling system useful in methods according to the present invention. **FIGS. 6B and 6C** are side views of the system of **FIG. 6A**.

[0031] **FIG. 7** is a side crosssection view of a system useful in methods according to the present invention.

DESCRIPTION OF EMBODIMENTS PREFERRED AT THE TIME OF FILING FOR THIS PATENT

[0032] Five stages of a method according to the present invention, are illustrated in FIGS. **1-5**.

[0033] In one dual pipe drilling method according to the present invention, a casing pipe CP is fitted with an open casing shoe as shown in **FIG. 1**. As the casing pipe CP is rotated and hammered, a plurality of cutters CT around the circumference of the drilling shoe DS remove material slightly thicker than the wall thickness of the following casing, allowing the casing to be advanced into the earth. Simultaneously, an inner drill pipe DP has a cutting bit member DB threadedly attached to the end of the drill pipe so that, when the inner drill pipe is rotated, remaining material inside of the casing pipe CP is removed, allowing the drill pipe DP and the casing pipe CP to be advanced through the earth E at the same rate. Compressed air CA is pumped down hole through the hollow drill pipe DP and out of the end of the drill bit DB, drill cuttings DC removed by the rotary (and hammering) action of both the casing shoe CS and the drill bit DB are evacuated up to the surface S through an annular space AS existing between the drill pipe DP and the casing pipe CP. Any suitable drilling techniques may be used to advance the inner drill pipe. These techniques may, optionally, include, but are not limited to, down-the-hole hammers systems (e.g., with a downhole hammer HM shown schematically in **FIG. 1**), tri-cone rotary bits, or conventional rotary drag bits. In certain soil conditions, drill pipe with external flights or augers may be utilized, with or without the assistance of compressed air, according to the present invention. When flight augers are used, the drill cuttings are transported primarily by the mechanical action of the rotating "flights" instead of by high velocity air moving up the annulus. This method can be used in certain geological formations when there exists a possibility of over-pressurizing the earth formation resulting in damage to surface structures. Also, certain environmental contaminants in which might be present in the drill cuttings can be easier to contain if compressed air is not used. From an economic standpoint, fuel consumption is reduced if the operation of the air compressor is eliminated without substantially reducing productivity. Optionally, a soap or other lubricant may be pumped down the drill pipe to reduce frictional forces between the auger flights and the material being transported. Additional drill and casing pipes are then added and the operation continues until a desired depth is reached.

[0034] Once a desired bore depth is reached, the inner drill pipes DP are retracted and removed, leaving the casing pipe CP in a drilled hole DH (see **FIG. 2**). Regardless of the stability of the native soils, the integrity of the hole is assured by the casing pipe CP. A heat exchange pipe loop PL (e.g. made of polyethylene), which has been previously filled with water W, pressurized, and sealed, is lowered into the dry cased hole DH (see **FIG. 3**). Any known earth loop and grout may be used, including, but not limited to, those disclosed in U.S. Pat. Nos. 5,435,387; 5,244,037; 5,261,251; 5,590,715; 5,758,724; and 6,276,438; 6,041,862; 6,250,371; 6,251,179; 5,968,257; 5,776,244; and 3,878,686 and in the references cited therein.

[0035] A thermally conductive grout mixture GM is now poured or pumped into the cased hole to completely fill the annular space AS between the heat exchange pipe loop PL and the casing pipe CP (see **FIG. 4**). The grout, preferably, contains suitable additives to retard the set of the grout until the casing pipe CP can be extracted.

[0036] As the casing pipe CP is extracted from the borehole (see **FIG. 5**), the heat exchange pipe loop PL remains in place. However, as the casing pipe CP is removed, the level of the grout GM in the bore drops, as it is no longer displaced by the casing pipe CP which has been removed. Additional grout GM is, preferably, added at certain times during the casing extraction procedure to ensure that the grout GM completely surrounds the heat exchange pipe loop PL before the natural earth has an opportunity to collapse (see **FIG. 5**). The grout GM effectively couples the heat exchange pipe loop PL to the native earth and seals the hole once the casing pipe CP has been extracted. Following complete removal of the casing pipe CP, the loop PL remains in the borehole and the grout material sets. In one aspect, the grout is at a level of about six feet down from the earth surface S; and, in certain aspects, this eliminates the need to remove and/or chip away grout at or near the surface, e.g. grout around poly pipe during a manifolding process.

[0037] In one aspect the present invention provides a drilling machine as shown in FIGS. **6A-6C** for simultaneously drilling and casing boreholes up to any desired depth, e.g. 500' deep holes under virtually all types of earth conditions. One preferred embodiment of such a drilling rig is a track mounted machine **10** as shown in FIGS. **6A-6C** which requires only a single operator to perform the complete drilling and casing function. The machine **10** on a movable track apparatus **18** has an on-board high pressure/volume air compressor **12**; (e.g. a Sullaire 450 psi×650 SCFM apparatus); an on-board carousel or magazine **14** to accommodate both drill pipe and casing pipe (e.g. for a 500' hole), with an automatic drill rod/casing handling mechanism **16** (e.g. as illustrated in U.S. Pat. No. 6,164,391) which moves tubulars from a magazine **14** (shown schematically in **FIG. 6**B); and an integral dual top drive rotary hydraulic hammer drill system **20** (shown schematically in **FIG. 6B**), e.g. such as the commercially available Krupp HB 60 apparatus, which also is a vibrating apparatus for densifying the grout. An erection apparatus **22** hydraulically powered raises and lowers a mast **24**.

[0038] In the method using the system in FIGS. **6A-6C** compressed air supplied by the on-board air compressor **12** is pumped down a wellbore to remove drilled cuttings from within the casing. In one particular method according to the present invention, augured drill pipe **32** with external flights **34** as shown in **FIG. 7** is used instead of or in addition to compressed air to remove drilled cuttings from the wellbore. The auger flights **34** move drilled cuttings up in the wellbore. Optionally, in any method herein, a shock sub is used above a string of drill pipe. Alternatively a top hammer (e.g.

as in the system **20, FIG. 6B**) hammers the drill pipe and no downhole hammer is used. In one aspect the top hammer is used to hammer augured drill pipe as shown in **FIG. 7**. In order to withstand the hammering impact of the percussion hammer, the augered drill pipe can be manufactured from alloys suitable for that purpose. Often alloys containing relatively high percentages of chrome and molybdenum are used. The manufacturing process can also include well-known welding, stress relieving, and heat treating procedures to obtain the desired metallurgical properties.

[**0039**] **FIG. 7** shows a system **30** according to the present invention useful in methods as disclosed herein to produce a wellbore for an earth thermal transfer loop. An outer casing string **40** extends down through the earth and has casing joints **41** threadedly connected together with a casing drill shoe **42** at the bottom of the casing string. Any suitable casing shoe or casing drill shoe may be used. An inner drill string **31** has the augured drill pipe **32** with an auger bit **33** at the bottom of the drill string **31**. Alternatively, any suitable known drill bit or drilling apparatus may be used and, optionally, a down hole motor may be used for drilling. Soap or some other lubricant may be pumped down or introduced into the drill string to reduce friction between drilled cuttings and the flights **34** (flow of such fluid indicated by arrow down into top of drill string). Fluid exits from the drillstring through holes **35** and is moved or pumped to the surface and out of the casing (indicated by arrows at top from within to outside casing). Optionally, lubricating and/or circulating fluid may also be pumped down to the bit which then exits through hole(s) **36**. Alternatively, such soap or lubricant is pumped down the casing to the bit.

[**0040**] The present invention provides, therefore, in at least certain aspects, methods for making a wellbore extending down into earth from an earth surface, the method including positioning a drilling apparatus at a desired location at the earth surface, the drilling apparatus having rotating and hammering apparatus for simultaneously rotating and hammering a dual tubular string into the earth, the dual tubular string with an outer casing string spaced apart by an annular space from an inner drill pipe string, both the outer casing and inner drill pipe string being hollow, a drill bit secured to a lowermost end of the inner drill pipe string and a casing drill apparatus secured at a lowermost end of the casing string, and drilling through the earth to form the wellbore by simultaneously rotating and hammering the dual tubular string with the drilling apparatus, and installing a thermal transfer heat loop in the thus-made wellbore.

[**0041**] The present invention, in certain embodiments, therefore provides a system for drilling a wellbore for a thermal transfer loop, the system having drilling apparatus positionable at a desired location at an earth surface, the drilling apparatus with rotating and hammering apparatus for simultaneously rotating and hammering a dual tubular string into the earth, the dual tubular string including an outer casing string spaced apart by an annular space from an inner drill pipe string, both the outer casing and inner drill pipe string being hollow, a drill bit or other drilling apparatus secured to a lowermost end of the inner drill pipe string, a casing drill apparatus secured at a lowermost end of the casing string, and a thermal transfer loop insertable into the wellbore.

[**0042**] In conclusion, therefore, it is seen that the present invention and the embodiments disclosed herein and those covered by the appended claims are well adapted to carry out the objectives and obtain the ends set forth. Certain changes can be made in the subject matter without departing from the spirit and the scope of this invention. It is realized that changes are possible within the scope of this invention and it is further intended that each element or step recited in any of the following claims is to be understood as referring to all equivalent elements or steps. The following claims are intended to cover the invention as broadly as legally possible in whatever form it may be utilized. The invention claimed herein is new and novel in accordance with 35 U.S.C. § 102 and satisfies the conditions for patentability in § 102. The invention claimed herein is not obvious in accordance with 35 U.S.C. § 103 and satisfies the conditions for patentability in § 103. This specification and the claims that follow are in accordance with all of the requirements of 35 U.S.C. § 112. The inventors may rely on the Doctrine of Equivalents to determine and assess the scope of their invention and of the claims that follow as they may pertain to apparatus not materially departing from, but outside of, the literal scope of the invention as set forth in the following claims.

What is claimed is:

1. A method for making a wellbore extending down into earth from an earth surface, the method comprising

positioning a drilling apparatus at a desired location at the earth surface, the drilling apparatus comprising rotating and hammering apparatus for simultaneously rotating and hammering a dual tubular string into the earth, the dual tubular string comprising an outer casing string spaced apart by an annular space from an inner drill pipe string, both the outer casing and inner drill pipe string being hollow, a drill bit secured to a lowermost end of the inner drill pipe string and a casing drill apparatus secured at a lowermost end of the casing string,

drilling through the earth to form the wellbore by simultaneously rotating and hammering the dual tubular string with the drilling apparatus, and

installing a thermal transfer loop in the wellbore.

2. The method of claim 1 further comprising

forcing compressed air with compressed air apparatus down an interior of the inner drill pipe string and up into the annular space to carry drilled cuttings to the earth surface.

3. The method of claim 1 further comprising

with automatic tubular handling apparatus automatically providing pieces of both casing and drill pipe as drilling commences to lengthen, respectively, the casing string and the inner drill pipe string.

4. The method of claim 1 further comprising

removing the inner drill pipe string following drilling of the wellbore down to a desired depth.

5. The method of claim 1 further comprising

grouting with grout material around the thermal transfer loop in the wellbore.

6. The method of claim 5 further comprising

the thermal transfer loop having a lowermost end and the method further comprising positioning said lowermost end about a foot from a bottom of the wellbore.

7. The method of claim 5 further comprising

pumping the grout material into the casing string to encompass the thermal transfer loop.

8. The method of claim 7 further comprising

with vibrating apparatus for vibrating the casing to densify the grout material.

9. The method of claim 7 further comprising

removing the casing string from the wellbore.

10. The method of claim 9 further comprising

adding additional grout material into the wellbore as the casing string is removed from the wellbore.

11. A method for making a wellbore extending down into earth from an earth surface, the method comprising

positioning a drilling apparatus at a desired location at the earth surface, the drilling apparatus comprising rotating and hammering apparatus for simultaneously rotating and hammering a dual tubular string into the earth, the dual tubular string comprising an outer casing string spaced apart by an annular space from an inner drill pipe string, both the outer casing and inner drill pipe string being hollow, a drill bit secured to a lowermost end of the inner drill pipe string and a casing drill apparatus secured at a lowermost end of the casing string,

drilling through the earth to form the wellbore by simultaneously rotating and hammering the dual tubular string with the drilling apparatus,

forcing compressed air with compressed air apparatus down an interior of the inner drill pipe string and up into the annular space to carry drilled cuttings to the earth surface,

with automatic tubular handling apparatus automatically providing pieces of both casing and drill pipe as drilling commences to lengthen, respectively, the casing string and the inner drill pipe string,

removing the inner drill pipe string following drilling of the wellbore down to a desired depth,

inserting a heat exchange earth loop into the wellbore through an interior of the casing string,

feeding grout material into the casing string to encompass the heat exchange earth loop, and

removing the casing string from the wellbore.

12. A system for drilling a wellbore, the system comprising

a drilling apparatus positionable at a desired location at an earth surface, the drilling apparatus comprising rotating and hammering apparatus for simultaneously rotating and hammering a dual tubular string into the earth,

the dual tubular string comprising an outer casing string spaced apart by an annular space from an inner drill pipe string, both the outer casing and inner drill pipe string being hollow,

a drill bit secured to a lowermost end of the inner drill pipe string,

a casing drill apparatus secured at a lowermost end of the casing string,

and a thermal transfer loop insertable into the wellbore.

13. The system of claim 12 further comprising

compressed air apparatus for forcing compressed air down an interior of the inner drill pipe string and up into the annular space to carry drilled cuttings to the earth surface.

14. The system of claim 12 further comprising

automatic tubular handling apparatus for automatically providing pieces of both casing and drill pipe as drilling commences to lengthen, respectively, the casing string and the inner drill pipe string.

15. The system of claim 12 further comprising

the drilling apparatus is track mounted.

16. The system of claim 12 further comprising

grout feeding apparatus for feeding grout material into the casing string to encompass the thermal transfer loop.

17. The system of claim 12 further comprising

vibrating apparatus for vibrating the casing to densify the grout material.

18. A system for drilling a wellbore, the system comprising

a drilling apparatus positionable at a desired location at an earth surface, the drilling apparatus comprising rotating and hammering apparatus for simultaneously rotating and hammering a dual tubular string into the earth,

the dual tubular string comprising an outer casing string spaced apart by an annular space from an inner drill pipe string, both the outer casing and inner drill pipe string being hollow,

a drill bit secured to a lowermost end of the inner drill pipe string,

a casing drill apparatus secured at a lowermost end of the casing string,

compressed air apparatus for forcing compressed air down an interior of the inner drill pipe string and up into the annular space to carry drilled cuttings to the earth surface,

automatic tubular handling apparatus for automatically providing pieces of both casing and drill pipe as drilling commences to lengthen, respectively, the casing string and the inner drill pipe string,

thermal transfer loop insertion apparatus for inserting a thermal transfer loop into a wellbore made by the drilling apparatus,

grout feeding apparatus for feeding grout material into the casing string to encompass the thermal transfer loop, and

vibrating apparatus for vibrating the casing to densify the grout material.

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